Risk Evaluation of Anomaly Event Occurrence Using Probe Vehicle Data

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1. Introduction

In this paper, we propose a real-time and quantitative evaluation method for standstill hazards that occur on road network in winter; the proposed method employs probe vehicle data and weather data.

The purpose of this study is to evaluate the risk before a standstill occurs and to enable road managers to respond to the standstill early. Japanese road managers are considering preventive road closure to remove snow thoroughly to prevent the standstill that occurs during heavy snowfall. This is because in Japan, large-scale standstills occur every year because of the effects of snow and road surface freezing. Japanese road managers have so far monitored changes in the speed and traffic volume observed by vehicle detectors. However, real-time and qualitative evaluations of the risk of anomaly events are lacking. Winter traffic regulations and snow-removal decisions have been based on weather forecasts and road manager experience. Ideally, traffic conditions and snow removal should be judged after monitoring the road conditions. Many studies analyzed the impact of winter weather conditions on traffic flow (Datla et al. (2013), Heqimi et al. (2018), Lu et al. (2019)). However, few studies have examined standstills because they rarely occur and because data collection is difficult. Several studies were focused on detecting anomaly events in road traffic. However, many of the proposed methods were aimed at early detection after an anomaly event has occurred (Horiguchi et al. (2013), Li and McDonal (2005)). In addition, many past studies dealt with events in which abrupt changes occurred at a given spot and the situation then propagated upstream, such as accidents occurring on access-controlled roads (Petty et al.(1997), Asakura et al. (2017), Takenouchi et al. (2019) (2005)). Accidents differ greatly from the anomaly events in winter, in which the situation changes gradually over a wide area and persists for a long time because of the effects of snow and freezing. Therefore, using a model proposed in a previous study without any modification often leads to misreporting of events.

2. Methodology

In this study, the speed with which a vehicle can travel safely in a certain section without being affected by traffic conditions and signals is defined as the road performance. We estimated the road performance by using probe vehicle data and evaluated the deterioration of the performance. We assumed a situation in which the road performance was significantly reduced because of the influence of winter weather, resulting in a high possibility of a standstill.

An image explaining the concept behind the proposed method is shown in Fig.1.The proposed method evaluates the risk of standstill when the real-time road performance estimated using the speed of a probe vehicle is significantly lower than the normal road performance. In this method, the real-time road performance is estimated using a state space model. The risk of occurrence of standstill is evaluated by comparing the deviation of the probability distribution representing the driving performance of roads in normal times and the probability distribution representing the driving performance of real-time roads. The difference between two probability distributions is evaluated using Kullback–Leibler (KL) divergence.

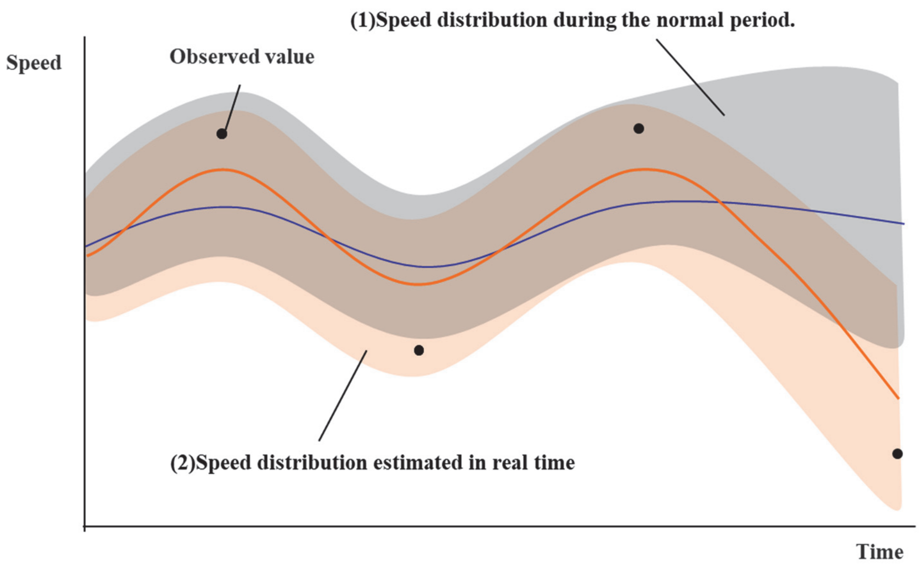

Fig.1 Concept image of the proposed method

3. Results

Fig. 2 shows the result of applying the proposed method to a section where a standstill occurred. The upper graph in Fig. 2 shows the temporal changes in the distribution of road performance during normal times and the distribution of real-time road performance. The graph in the middle in Fig. 2 shows the time variation of KL divergence. The lower graph in Fig. 2 shows the temporal change in snowfall. Since KL divergence suddenly increased before the standstill occurred, the proposed method can evaluate the increased risk of anomaly events.

Fig. 3 shows the KL on the map corresponding to the situation in which the proposed method was applied to the entire route in which the standstill occurred. The size of the red square on the map indicates the KL divergence. Two days before the standstill, the KL divergence rarely had a high value, but one day before the occurrence of an anomaly event, the value was high for the entire route. KL was very high when the standstill occurs.

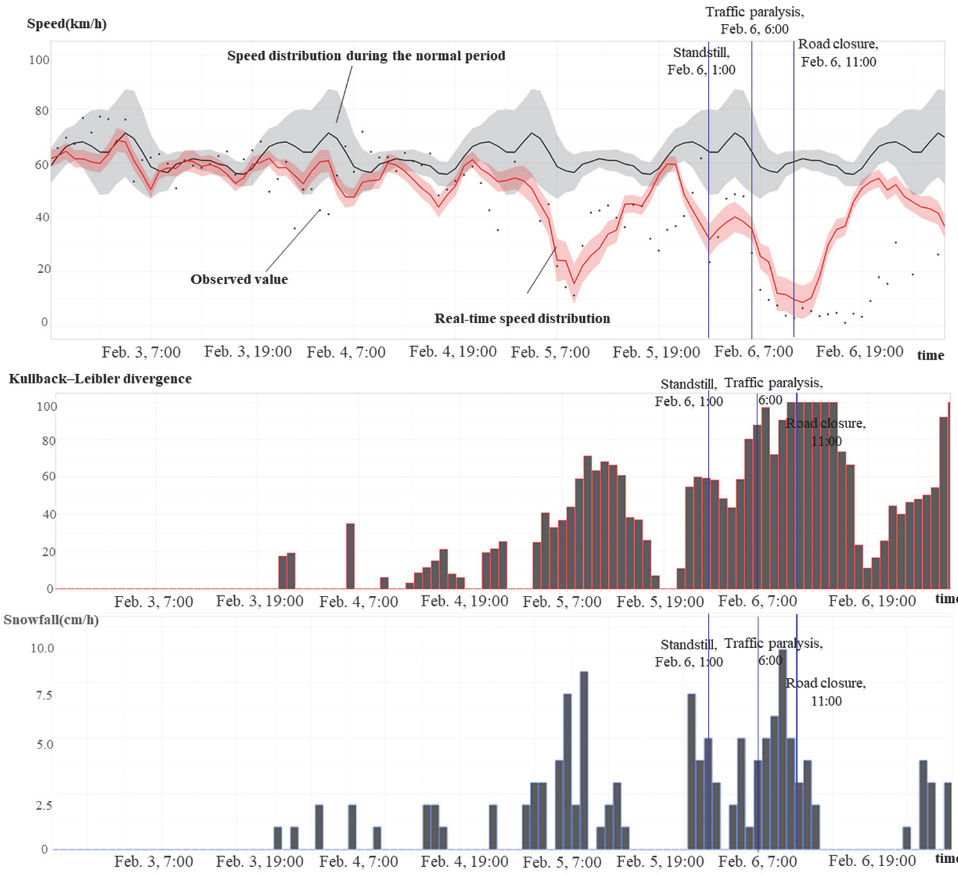

Fig.2 Results of applying the proposed method to the section in which the standstill occurred

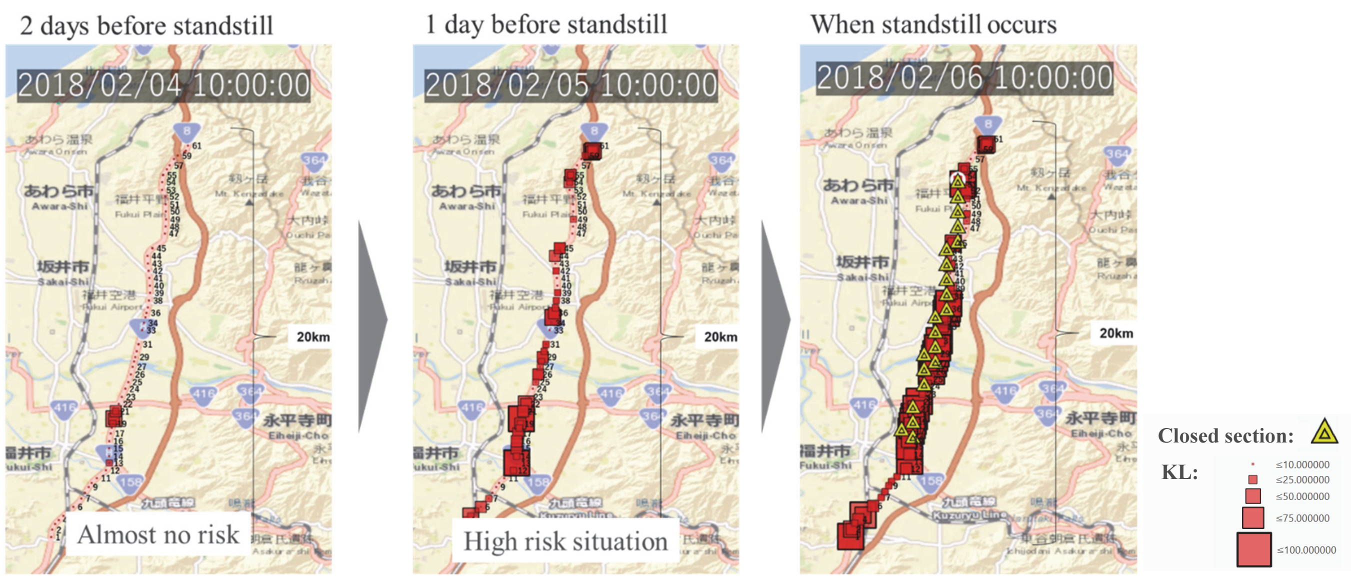

Fig.3 Results of applying the proposed method to routes where standstills occurred

4. Conclusion

In this paper, we propose a method to evaluate standstill risk quantitatively and in real time over a wide range of general road networks. Our method will help reduce the influence of standstill in winter on road traffic. The effectiveness of the proposed method was confirmed by applying it to routes where standstills actually occurred. The proposed method can evaluate the risk of standstill before it occurs. Since the proposed method employs a state space model, it can take into account probabilistic errors and reduce false alarms. The proposed method is useful because it is less restrictive than the current monitoring method in terms of monitoring range and cost.

In the future, further issues in this method will be identified with the help of road managers who have used the method.

5. Acknowledgement

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6. References

1) Datla, S., Sahu, P., Roh, J.H, Sharma, S.: A comprehensive analysis of the association of highway traffic with winter weather conditions, Procedia-Social and Behavioral Sciences, pp.104 497-506, 2013.
2) Heqimi, G., Gates , J. T, Kay, J. J.: Using spatial interpolation to determine impacts of annual snowfall on traffic crashes for limited access freeway segments, Accident Analysis & Prevention, Vol. 121, pp.202-212, 2018.
3) Lu, Z., Kwon, J. Tae., Fu, L.: Effects of winter weather on traffic operations and optimization of signalized intersections, Journal of Traffic and Transportation Engineering, Vol.6, Issue 2, pp.196-208, 2019.
4) Horiguchi, R., Iijima, M., Kobayashi, M. and Hanabusa, H.: Traffic anomaly detection for surface street networks with the mesh-wised traffic indices on macroscopic fundamental diagram, OPTIMUM 2013 International Symposium on Recent Advances in Transport Modelling, pp. 1-7, 2013.
5) Li, Y. and McDonald, M.: Motorway incident detection using probe vehicles, Proceedings of the Institution of Civil Engineers-Transport, Vol. 158, pp. 11-15, February 2005.
6) Petty, K. F., Skabardonis, A. and Varaiya, P. P.: Incident detection with probe vehicles: performance, infrastructure requirements and feasibility, Transportation Systems 1997,A Proceedings Volume from the 8th IFAC/ IFIP/ IFORS Symposium, Chania, Greece, June 16-18, 1997, Vol. 1, pp.125-130, 1997.
7) Asakura, Y., Kusakabe, T., Nguyen, L., X., and Ushiki, T.: Incident Detection Methods using Probe Vehicles with on-board GPS Equipment, Transportation Research Part C: Emerging Technologies, 2016.
8) Takenouchi, A., Kawai, K., Kuwahara, M.: Traffic state estimation and its sensitivity utilizing measurements from the opposite lane, Transportation Research Part C: Emerging Technologies, Vol.104, pp 95-109, 2019.